

Reducing Tardiness from Scheduled Start Times by Making Adjustments to the Operating Room Schedule

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BACKGROUND: Tardiness from scheduled start times is a common source of frustration for both operating room (OR) personnel and patients. Factors that influence tardiness were quantified in a companion paper and have been used to develop interventions that have the potential for reducing tardiness.

METHODS: Data from two surgical suites were used to compare the effectiveness of several interventions to reduce tardiness, including i) moving cases to different ORs on the afternoon of surgery, ii) recalculating the OR schedule when it is published to correct for average lateness in first cases of the day, iii) recalculating the OR schedule when it is published to correct for average service-specific case duration bias, and iv) scheduling a gap (time buffer) before the cases of a "to follow" surgeon if the day is expected to end early. These last three interventions involve creation of a modified schedule with revised start times that are more accurate for both patient and "to follow" surgeon. The surgeon performing the first case of the day would not be affected.

RESULTS: Moving cases to different ORs when a room was running late produced a 50%–70% reduction in the tardiness for those cases that were moved. However, overall tardiness in each suite was reduced by only 6%–9%, because few cases were moved. Scheduling a gap between surgeons if the day was expected to end early reduced tardiness by more than 50% for those cases that were preceded by gaps. However, overall tardiness in each suite was reduced by only 4%–8%, because few gaps could be scheduled. In contrast, correcting for the combination of lateness in first cases of the day and service-specific case duration bias reduced overall tardiness in each suite by 30%–35%.

CONCLUSIONS: Interventions which involve small numbers of cases have little potential to reduce overall tardiness. Generating a modified or auxiliary OR schedule that compensates for known causes of tardiness can significantly reduce patient and "to follow" surgeon waiting times. Modifying the OR schedule to create revised start times for patients and "to follow" surgeons involves interventions that are simple to perform. The official schedule is not changed and case sequencing is not altered. Results do not depend on changing surgeon, anesthesia provider, or nursing behavior.

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Many surgical suites have undertaken initiatives to reduce tardiness from scheduled start times. Changing human behavior can successfully reduce late starts for first cases of the day¹⁻⁵ and decrease turnover times.^{4,6}

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Methods have been refined for improving case duration predictions even when few historical data are available,⁷⁻¹¹ but the duration of each individual case will always have a random component that can never be predicted with certainty.¹²⁻¹⁷ To eliminate tardiness, a surgical suite would have to allow sufficient time for each case to ensure timely completion.^{11,15,18,19} The result would be low utilizations with wasted time in the middle of day, because many cases would finish early.^{18,20-22}

In this article, interventions are proposed to reduce tardiness in surgical suites. These interventions do not require changing human behavior or performing complex mathematical calculations in real time. Only basic historical data are required to supplement the daily schedule: scheduled and actual start times, scheduled and actual case durations, and surgical service. Development of these methods depended on understanding the various factors that contribute to tardiness. Such insight was gained from discrete event simulations²³ of

individual operating rooms (ORs) and the preceding companion article,²⁴ which used real data from two surgical suites with interacting ORs to determine tardiness under a variety of conditions.

We found that overall tardiness in the two suites did not depend on the individual durations of preceding cases, but only on their total duration.²⁴ Tardiness did not continue to increase throughout the day as we had expected,²³ but decreased later in the afternoon when cases were moved to different ORs. Tardiness was not reduced if a surgeon followed himself in the same OR rather than another surgeon. Tardiness was not increased by prolonged turnovers. In contrast, tardiness was greater when the scheduled length of the workday was longer. Tardiness was greater when first-case-of-the-day starts were excluded from analysis. Tardiness depended on the expected inefficiency of use of OR time, increasing when staff thought the day would finish early and decreasing when the day would finish late. Finally, tardiness was affected by service-specific case duration bias.

Based on these results, we assessed several interventions to determine the extent to which they would reduce tardiness in the two surgical suites.²⁴ None of the methods described involve changing staff behavior, which can be difficult to accomplish. Likewise, none involves changing the dates of surgery or changing the sequence of cases in an OR,^{11,14,18,19,25} which can be disruptive for both surgeons and patients. Instead, the interventions involve mathematical "corrections" to recalculate case start times, with creation of a modified or auxiliary OR schedule that compensates for predictable causes of tardiness.

METHODS

Detailed methods for analysis of tardiness are described in the preceding paper.²⁴

Data were from all surgical cases performed at an academic medical center in either its tertiary surgical suite of 24 ORs (MAIN suite), or in its ambulatory surgery center (ASC) suite of six ORs. Analysis was limited to cases performed on scheduled workdays from January 2005 to December 2006. Weekends and holidays were excluded. Data included tentative room assignments, scheduled start times, and predicted case durations as listed on the "final" surgery schedule issued about noon the working day before surgery, as explained in.²⁴ Additional data included the room in which each case was performed and the actual times that each patient entered and exited the OR. The number of cases performed was 26,003 in the MAIN suite, of which 2871 were added the day of surgery (add-on cases), and 11,541 in the ASC, of which 122 were added the day of surgery. The two suites were analyzed separately.

Tardiness and Lateness

Tardiness for each case was quantified as the difference between the time the patient actually entered the OR and the scheduled start time of the case.²⁶ If a

case started early or on-time, tardiness was zero for that case. Cases added to the OR schedule on the day of surgery were not included in calculations of tardiness or lateness.

Tardiness was expressed as the average of either tardiness per case or tardiness per OR per day, based on all cases in all ORs. Tardiness per case represents the average time that patients must wait beyond the scheduled start times of their cases. For a surgeon, average waiting time is the average tardiness per case of only the first case in each list of cases. Average tardiness per OR per day is the easiest to comprehend in terms of its impact on OR activities.

Lateness for a case is the signed difference between the scheduled start time of the case and its actual start time. If the case started later than scheduled, lateness is positive. If the case started early, lateness is negative. First cases of the day that did not start later than scheduled were an average of 7 s early in the MAIN suite and 8 s early in the ASC. Thus, for the two suites studied, tardiness was indistinguishable from lateness for first cases.

First-Case-of-the-Day Starts

A case was considered a first-case-of-the-day start if it was performed as the first case of the day and either of two additional conditions was satisfied: i) The case was scheduled to begin within 30 min of the start of the scheduled workday (start of workday, 8:00 AM Mondays and Tuesdays; 7:15 AM Wednesdays, Thursdays, and Fridays), or ii) The case was moved forward in the schedule so that it actually began within 30 min of the start of the scheduled workday.

List of Cases

The series of cases that a surgeon is scheduled to perform sequentially in the same OR on a single day was considered the surgeon's "list of cases." Intervening turnovers were included in the time to complete a list of cases.

"To Follow" Surgeons

If one surgeon is scheduled to follow another surgeon in the same OR, and cannot begin his list of cases until the first surgeon finishes, the second surgeon is considered a "to follow" surgeon.

Under-Utilized and Over-Utilized Time

Under-utilized time is the hours for which staffing have been planned but the OR sits idle.²⁴ Over-utilized time is the hours that cases extend beyond the length of the workday for which staffing has been planned.^{25,27}

Statistical Analyses

Data calculations and paired Student's *t*-test were performed in Excel or Excel Visual Basic for Applications.

To eliminate the effects of autocorrelation,^{23,24} mean tardiness and case duration bias (modified to include

turnovers) were determined independently for 25 successive nonoverlapping 4-wk periods.²⁸⁻³¹ Values are thus reported as the average \pm standard error (SE) of the means of 25 four-week periods. At least 10 cases must have been performed in a given 4-wk period for that period to be included in the average. For ease of reading, standard errors <1 min are reported as 1 min (0:01). SE $<1\%$ are reported as 1%. The significance of differences between averages and of interventions to reduce tardiness was determined using paired Student's *t*-test applied to the means from the 25 time periods.

Interventions to Reduce Tardiness

Several adjustments to the OR schedule were tested to determine their effects on tardiness. Some cases had been reassigned and were physically moved to different ORs, presumably to reduce tardiness or over-utilized OR time in the two suites. Other interventions were hypothetical and were performed retrospectively "on paper." They did not influence actual OR activities.

Moving Cases to Different ORs

Almost all surgical suites move cases on the afternoon of surgery. Moving of cases may reduce tardiness^{18,32-35} and over-utilized OR time.²⁷ Since moving of cases is a common practice, the magnitude of the savings in tardiness resulting from this intervention was used as a metric for judging the effectiveness of other methods designed to reduce tardiness. Many studies have considered the process that OR managers should use when making decisions to move cases and the theoretical impact that such decisions would have on over-utilized time. In contrast, this article focuses on the reduction in tardiness that resulted from actual decisions to move cases in two real surgical suites.

Examination of the data revealed that numerous cases had been moved to different ORs on the afternoon of surgery. To determine the impact of these adjustments, tardiness was recalculated as though the cases had not been moved. We assumed that cases were performed in the ORs to which they were originally assigned and in the sequence originally planned. Actual case durations and turnover times were used. To be included in the recalculation, cases that were moved or were displaced by a move must have been scheduled to begin, and must have actually begun, at least 4 h after the start of the workday. Cases that were moved the evening before surgery or the morning of surgery were not included because they were probably moved for reasons other than reducing tardiness and over-utilized time. For example if cases scheduled for 7:15 AM in Room #1 and 2:00 PM in Room #2 were switched because paperwork was incomplete for the first case, neither case was considered to have been moved on the afternoon of surgery.

We did not establish "rules" for moving cases and recalculate the OR schedule based on simulated decisions to move cases. Instead, only real data were used and only those cases that were physically moved were

considered to have been moved. In practice, decisions to move cases were made by as many as eight different OR managers. Each individual had his or her own criteria for determining when cases should be moved. Managers must also deal with unusual situations³⁶ that cannot be incorporated into a limited set of rules, such as the availability of an assisting surgeon not listed on the official schedule. Because such heterogeneity in decision-making and in circumstance occurs in real life, we accepted the decisions that were actually made under the conditions that actually existed. We did not "second guess" decisions to move or not to move cases.

Creation of an Auxiliary Surgery Schedule

The interventions that follow were performed on historical data collected over 2 yr. The final schedule issued about noon each workday was modified to create revised start times based on the interventions below, then actual case start times and durations were used to determine the effect of each intervention on tardiness using the revised start times. To implement these interventions in a real OR, we would perform calculations on the surgery schedule at the time of its release or publication. We would produce an unofficial or auxiliary schedule in which start times had been manipulated to compensate for known causes of tardiness. The auxiliary schedule would only be used for informing patients and "to follow" surgeons of their scheduled start times (see Ref. 37). These two groups should then experience less tardiness because their scheduled start times had been revised. Note that every case would still be performed as planned according to the original schedule, subject to any changes imposed by the OR managers. The majority of OR staff would not even be aware of the existence of this auxiliary schedule. Scheduling of cases would not be affected in any way. Only the start times provided to patients and "to follow" surgeons would change.

Correcting for Lateness of First Cases of the Day

Average lateness was determined for first cases of the day. Data from all surgical services were pooled to generate a single value for each surgical suite. Revised start times for all cases were then determined by adding the average lateness of first cases of the day to the start times of both first cases and all subsequent cases. Tardiness was recalculated using these revised start times and actual case durations and turnover times.

To provide an analogy, suppose that a movie theater lists the start time for a show as 7:15 PM. However, movies at commercial theaters are generally preceded by advertisements for the snack bar and previews of other shows. Most people realize that the main feature will not begin until about 7:30 PM. Patrons can mentally plan on a start time of 7:25 PM to reduce the time they will have to wait for the main feature.

Similarly, if the average lateness of first cases is 10 min, the OR schedule can be recalculated so that every

case is scheduled to begin 10 min later. This can be done in practice by scheduling a pseudocase 10 min long at the start of the workday, without a turnover time. Alternatively, the duration of the first case can be increased by 10 min, or the turnover time at the end of the first case can be increased by 10 min. Recalculated start times from the auxiliary schedule determine when patients and “to follow” surgeons should expect their cases to begin. No one else will be affected, since case sequencing has not been altered. Every case will still be performed on the same date and in the same OR as originally scheduled.

Correcting for Case Duration Bias

Case duration bias is the difference between the actual time required to perform a series of cases and their scheduled duration, including turnover times. Bias is normalized to 8 h of actual OR time.^{25,38} Case duration bias was calculated separately for each surgical service. Turnover times were included because they can contribute to tardiness. Although turnovers are not usually included when calculating bias,³⁸ we use the phrase “case duration bias” anyway because almost all bias will be caused by the cases rather than the turnovers.

Creation of an auxiliary schedule and adjustment of scheduled durations to compensate for positive case duration bias should reduce tardiness. The following steps illustrate how scheduled case durations were modified based on the systematic case duration bias exhibited by each surgical service: i) The scheduled duration was determined for each case, including turnovers. ii) Bias for the case was calculated by dividing the scheduled duration by 8 h, and then multiplying by the systematic bias per 8 h of OR time for that service.* iii) The bias for that case was added to the scheduled duration to generate an adjusted duration. iv) Adjusted durations were used to generate an auxiliary schedule with revised start times for all cases that were not first cases of the day. v) Tardiness was recalculated based on the revised start times in the auxiliary schedule. Again, if these steps were implemented and performed on a daily basis, the official OR schedule and case scheduling would not be affected.

Case duration bias was calculated for each surgical service rather than each subspecialty or surgeon.¹⁵ At

*Corrections for case duration bias assumed that the bias for an individual case was linearly related to its scheduled duration. For example, the duration of a case scheduled to last 4 h was increased by an amount equal to half of the bias per 8 h of OR time. Bias for each list of cases was thus apportioned among individual cases so that the total bias for all the individual cases in the list would equal the bias for the entire list. Calculated over-utilized time was therefore unchanged. In reality, however, bias for an 8 h case was about 3 times the bias of a 1 h case. A Bayesian method¹¹ could have been used, with the modeled¹⁶ bias for each case applied to the logarithms of case durations. However, the resulting sum of the scheduled durations of the individual cases in the list would no longer be an unbiased estimator for the time required to complete the entire list of cases. Consequently, over-utilized time would change.

the hospital studied, OR time was planned for 12 surgical services that used the MAIN suite and six services that used the ASC. The services were actually departments or divisions within the hospital. In practice, each service then planned OR time for individual surgeons or small groups of surgeons who practiced in the same subspecialty.^{25,39}

Scheduling a Gap or Delay (Sometimes Called “Time Buffer” or “Slack”) Between Cases of Different Surgeons When the Day Was Expected to End Early

When one surgeon was scheduled to follow another surgeon, the start time of the second surgeon (“to follow” surgeon) was delayed in the auxiliary schedule to create a buffer between cases.^{11,18,22} This buffer reduced the likelihood that the case of the “to follow” surgeon would be tardy in the event the first surgeon’s cases lasted longer than scheduled.

The optimal length of the workday for which staffing should be planned was 10 h in the MAIN suite and 8 h in the ASC (see companion article.²⁴ When the workday was scheduled to end earlier, the last surgeon of the day was assigned the latest possible start time that would still allow him to complete his list of cases by the end of the workday. The amount of time allotted for the “to follow” surgeon was the 90% upper prediction bound for the duration of his list of cases.^{18,22} If the required 90% upper prediction bound would have necessitated a start time that was earlier than the originally scheduled start time, no gap could be scheduled. When gaps were possible, cases were rescheduled to begin no later than 1 h after their original start times.

Revised values for the tardiness of all cases were determined using rescheduled start times that included gaps between surgeons. Actual case durations were used, and actual turnover times were used unless the resulting gaps exceeded the turnover times. In addition to tardiness, resulting under-utilized time and over-utilized time were calculated to ascertain the impact of gaps in the schedule on the efficiency of use of OR time.^{25,27}

The 90% upper prediction bound for the duration of each list of cases^{18,22} was determined by multiplying the scheduled duration by a constant. The constant was equal to the 90th percentile of the ratios between the actual duration of each list of cases, including turnovers, and the scheduled duration of the list.³⁷ Ratios for all lists for all surgeons were pooled within each suite. Ratios were derived only from lists of cases scheduled to last <4 h in the MAIN suite or 3 h in the ASC, because these were considered the maximum durations of lists that would be scheduled for “to follow” surgeons. Confidence intervals (CI) for 90th percentiles were determined using the Clopper-Pearson method.⁴⁰ The 90th percentiles of the ratios were 1.54 (95% CI 1.53–1.56) in the MAIN suite and 1.45 (95% CI 1.43–1.48) in the ASC. Scheduled durations for each list of cases were therefore multiplied by

Table 1. Interventions to Reduce Tardiness

	MAIN surgical suite			ASC		
	Per case	Per OR per day	Percent	Per case	Per OR per day	Percent
Tardiness for all cases scheduled at least 1 d in advance	0:29 ± 0:01	1:03 ± 0:01		0:24 ± 0:01	1:38 ± 0:02	
Reduction in tardiness attained by moving cases to different ORs later in the day ^a	0:02 ± 0:01	0:04 ± 0:01*	6% ± 1%	0:02 ± 0:01	0:10 ± 0:01*	9% ± 1%
Those cases that were moved						
Number of cases	1.6 ± 0.1 per day		3.3% ± 0.2%	1.0 ± 0.1 per day		4.4% ± 0.3%
Tardiness	0:48 ± 0:04			0:22 ± 0:01		
Tardiness if cases had not been moved	1:48 ± 0:05			1:21 ± 0:03		
Reduction in tardiness	0:59 ± 0:08		49% ± 7%	0:58 ± 0:03		71% ± 2%
Lateness of first cases of the day	0:08 ± 0:01			0:04 ± 0:01		
Tardiness after correcting for lateness of first cases of the day	0:24 ± 0:01	0:53 ± 0:01		0:22 ± 0:01	1:29 ± 0:02	
Reduction in tardiness ^b	0:04 ± 0:01	0:09 ± 0:01*	16% ± 1%	0:02 ± 0:01	0:08 ± 0:01*	9% ± 1%
Tardiness after correcting for service-specific case duration bias	0:20 ± 0:01	0:44 ± 0:01		0:18 ± 0:01	1:13 ± 0:02	
Reduction in tardiness ^c	0:08 ± 0:01	0:18 ± 0:01*	29% ± 1%	0:06 ± 0:01	0:24 ± 0:01*	25% ± 1%
Tardiness after correcting for both lateness of first cases of the day and service-specific case duration bias	0:19 ± 0:01	0:40 ± 0:01		0:16 ± 0:01	1:08 ± 0:02	
Reduction in tardiness	0:10 ± 0:01	0:22 ± 0:01*	35% ± 1%	0:07 ± 0:01	0:29 ± 0:01*	31% ± 1%
Reduction in tardiness attained by scheduling a gap before the last list of cases for the day	0:02 ± 0:01	0:04 ± 0:01	8% ± 1%	0:00 ± 0:01	0:03 ± 0:01	4% ± 1%
First cases in lists for which a gap could be scheduled						
Number of cases	4.3 ± 0.1 per day		9.1% ± 0.1%	0.88 ± 0.05 per day		3.8% ± 0.2%
Tardiness	0:48 ± 0:01			0:40 ± 0:01		
Tardiness if gap scheduled ^d	0:23 ± 0:01*			0:15 ± 0:01*		
Reduction in tardiness	0:25 ± 0:01		52% ± 1%	0:25 ± 0:01		62% ± 1%
Under-utilized time						
If no gap scheduled		1:39 ± 0:02			1:01 ± 0:02	
If gap scheduled ^d		1:34 ± 0:02 ns			0:57 ± 0:02 ns	
Over-utilized time						
If no gap scheduled		0:45 ± 0:01			0:30 ± 0:01	
If gap scheduled ^d		0:46 ± 0:01 ns			0:31 ± 0:01 ns	

Time values are expressed as h: min and are the average ± se of 25 four-wk periods. se less than 1 min are displayed as 1 min (0:01). se less than 1% are shown as 1%.

OR = operating room; ASC = ambulatory surgery center.

^a Comparing tardiness if cases had not been moved to observed tardiness with moving of cases.

^b Comparing tardiness before and after correcting for lateness of first cases of the day.

^c Comparing tardiness before and after correcting for service-specific case duration bias.

^d Compared with no gap scheduled.

* $P < 0.001$; ns not significant. In the 25 four-wk periods, 797 and 513 cases were moved to different ORs in the MAIN suite and the ASC. Gaps were "scheduled" before 2133 and 408 lists of cases in the MAIN suite and the ASC, which constituted 64% and 47% of all lists involving "to follow" surgeons.

1.50¹¹ to yield the 90% upper prediction bound for the duration of each list.

RESULTS

Moving Cases to Different ORs

Moving cases to different ORs reduced tardiness by an average of 4 min and 10 min per OR per day in the MAIN suite and the ASC (Table 1). These reductions represent 6% and 9% of tardiness in each suite. For those cases that were moved to different ORs, the reduction in tardiness was substantial, 59 min per case

(49%) in the MAIN suite and 58 min per case (71%) in the ASC (Table 1). Thus, moving cases greatly benefited the surgeons and patients whose cases were moved and reduced their waiting times. However, moving cases had a much smaller impact on overall tardiness in the two suites because so few cases were moved. On average, <5% of cases were moved each afternoon in both the MAIN suite and the ASC (Table 1).

A common perception is that tertiary surgical suites, but not ASCs, are often disrupted by add-on

cases that are placed on the schedule the day of surgery.^{18,19,34} In fact, add-on cases were 11% and 1% of the total cases in the MAIN suite and the ASC. In each suite, 83% of cases added the day of surgery were either last cases of the day or were scheduled to begin during the evening or nighttime hours, between 6 PM and 7 AM. Thus, few cases were moved to different ORs or were delayed to accommodate add-on cases.

Rather, add-on cases may influence tardiness by limiting opportunities to move cases. Add-on cases were performed in ORs that finished first, and so other cases could not be moved to those ORs. The OR manager in the MAIN suite had less flexibility to reschedule cases, which explains why moving of cases produced a much smaller reduction in tardiness in the MAIN suite (4 min per OR per day) than the ASC (10 min per OR per day). In addition, add-on cases may prevent a tertiary surgical suite from scheduling a gap before a “to follow” surgeon if the day is expected to end early (see below). ORs that are scheduled to finish before the end of the workday are reserved for add-on cases. After the “final” schedule was issued, 25.7% ± 0.2% of cases in the MAIN suite, compared with 8.6% ± 0.4% of cases in the ASC, were either moved or added on.

Correcting for Lateness of First Cases of the Day

Lateness of first cases of the day averaged 8 min in the MAIN suite and 4 min in the ASC (Table 1). Creation of an auxiliary OR schedule to correct for lateness in first cases reduced tardiness by 9 min per OR per day (16%) in the MAIN suite and 8 min per OR per day (9%) in the ASC (Table 1). The magnitude of the effect was similar to that of moving cases.

Correcting for Case Duration Bias

Case duration bias, or systematic under-estimation of case durations, ranged from negative 24 min to 67 min per 8 h of OR time, depending on the surgical service and suite. Recalculating the OR schedule to correct for the case duration bias of each service reduced tardiness by a total of 18 min per OR per day (29%) in the MAIN suite and 24 min per OR per day (25%) in the ASC (Table 1). The reduction in tardiness was greater for those services with greater bias (Fig. 1).

Correcting for Both Lateness of First Cases and Case Duration Bias

Modifying the OR schedule to incorporate corrections for both lateness of first cases of the day and case duration bias resulted in reductions in tardiness of 22 min and 29 min per OR per day (35% and 31%) (Table 1). These reductions in tardiness are large when compared to the 6% and 9% reductions achieved by moving cases at the end of the day.

Scheduling a Gap Between Surgeons

Scheduling a gap before the list of cases of the last surgeon in an OR resulted in only 3 min and 4 min (4%

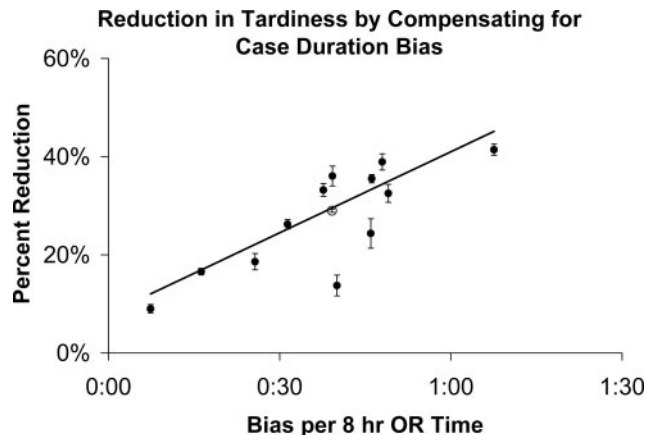


Figure 1. Percentage reduction in tardiness per case resulting from correction for case duration bias in the MAIN suite. Bias is expressed per 8 h of operating room (OR) time. Bias was calculated separately for each of 12 surgical services and is shown as the mean of up to 25 four-wk periods. An increase in case duration bias was associated with greater reductions in tardiness per case ($P < 0.0001$, $F[1,273] = 266.6$). Line is a least squares fit to 273 four-wk periods from 11 surgical services. Open circle shows aggregate data for the entire suite. Error bars show \pm SE.

and 8%) reductions in tardiness per OR per day (Table 1). The effect was thus quite small.

We examined cases that followed gaps in more detail. Tardiness for those cases was reduced by an average of 25 min per case in both the MAIN suite and the ASC, representing reductions of 52% and 62% (Table 1). Thus, scheduling a gap before the list of cases of a “to follow” surgeon would greatly benefit the surgeons and patients whose scheduled start times were changed. Their waiting times would be reduced. However, gaps could be scheduled before only about four lists of cases each day in the MAIN suite and one list in the ASC (Table 1).

A potential disadvantage associated with scheduling a gap between surgeons is that the cases of the “to follow” surgeon could adversely affect OR efficiency by running past the end of the scheduled workday 10% of the time. As expected, scheduling a gap between surgeons reduced under-utilized time (Table 1). However, the reduction was only 4 min to 5 min per OR per day, which is neither statistically significant nor practically important. Scheduling an appropriate gap before “to follow” surgeons would not have caused them to run past the end of the scheduled workday. Over-utilized time would have been increased by 1 min per OR per day in each suite, a difference that is not statistically significant.

DISCUSSION

Moving cases from one OR to another to reduce tardiness is a common practice at many hospitals.^{18,19,33–35,41} Moving of cases therefore serves as a reference for interpreting the relative effectiveness of other interventions designed to reduce tardiness. We found that moving cases to different ORs greatly

reduced tardiness for those few cases that were moved. However, when this reduction in tardiness was spread across all cases, moving of cases reduced tardiness in the two suites by 6%–9%. Thus, the overall effect was relatively small.

Several other interventions that might reduce tardiness were compared to the effects of moving cases. Scheduling a gap before the first case of a “to follow” surgeon when the day was expected to finish early reduced tardiness for the surgeons and patients involved in those cases. Overall, tardiness in the two suites was reduced by 8% and 4%. Although some hospitals may balk at the idea of scheduling a gap between cases, the intervention is realistic. In many European countries, common practice is to schedule two sessions per operating theater each day, with a break for lunch.⁴² This practice is analogous to creating gaps between cases.

Although tardiness for an entire suite was affected only minimally by moving cases to different ORs in the afternoon or by scheduling a gap before the list of cases of a “to follow” surgeon, these interventions are worthwhile from the perspective of the affected surgeons and patients. They resulted in large reductions in tardiness for the cases that were moved or rescheduled.

To have an important impact on tardiness for a substantial number of individuals, however, interventions must involve large numbers of cases. Tardiness was significantly reduced by two interventions that affected the start times of many cases on the auxiliary schedule. Fortunately, these interventions are much easier to implement than moving of cases or scheduling a gap between surgeons. In combination, correction for lateness of first cases of the day and case duration bias reduced tardiness in the two suites by 35% and 31%.

Creation of an auxiliary OR schedule is easy and practical, and could thus play an important role in helping to reduce tardiness at many hospitals. Since actual start times are not altered, the surgery schedule is not disrupted. Changes in nurse or physician behavior are not required. Staff will not be burdened by inconveniences associated with moving large numbers of cases³² or changes in patient flow or work patterns.^{43–46}

When the surgery schedule is published each day, new start times for each case can readily be calculated after compensating for lateness of first cases and case duration bias. Revised start times in the auxiliary schedule can be used to determine patient arrival times and to determine the start times of cases for “to follow” surgeons. Tardiness and patient waiting^{11,23,37,47,48} in each suite would be decreased by one-third (Table 1).

These methods should be applicable to other institutions with substantial lateness of first cases or substantial case duration bias. Absent such characteristics, our methods would produce smaller reductions in

tardiness. Similarly, moving of cases may have a larger impact on tardiness at facilities that shuffle a greater proportion of their cases. It may have a smaller impact at facilities with a large number of add-on cases that prevent moving of other cases.

A potential problem could arise if the auxiliary schedule is posted in the ORs, where it may simply replace the official published schedule. Staff who learn that the schedule expects the day to start 8 min late may plan on starting 8 min late. The result may be delays of 16 min. However, anesthesia providers and other OR staff generally ignore scheduled start and stop times presented in printouts and computer displays when making decisions that do not involve first cases of the day.^{34,35,49} To ensure the auxiliary schedule does not “contaminate” the official one, only certain individuals, such as patients and “to follow” surgeons, should be privy to the revised start times. Selective distribution of the auxiliary schedule is especially realistic at facilities in which patients are notified by an automated calling system or by clerks reading from a computer display.

SUMMARY

This article is the second of two sequential articles. In the first article,²⁴ we investigated several factors that could potentially contribute to tardiness. We also examined differences between patient waiting and surgeon waiting. Using information learned from those studies, we selected several mathematical interventions that might reduce tardiness without having to change staff behavior. Recalculating the OR schedule to correct for lateness of first cases of the day and case duration bias were especially effective at reducing tardiness in the two suites studied. Such interventions require minimal effort and thus can be employed at many surgical facilities to reduce tardiness from scheduled start times.

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